invention all include an $\alpha$ phase of about 30 percent or more of the total phase area to practice the invention. This is because the $\alpha$ phase is the only phase that gives metal alloys a degree of cold workability. In other words, if the copper alloy has less than about 30% $\alpha$ phase comprising the total phase area of the metal, then the copper alloy is not cold workable and can not be further processed by cutting in any practical manner. Therefore, all of the copper alloys of the present invention have a metal construction that is a composite phase that is an $\alpha$ phase matrix to which other phases are provided.

[0086] As mentioned above, the presence of silicon in the copper alloys of the present invention is to improve the machinability of the copper alloy, and this occurs partly because silicon induces a $\gamma$ phase. Silicon concentrations in any one of the $\gamma$, $\kappa$, and $\mu$ phases of a copper alloy are 1.5 to 3.5 times as high as that in the $\alpha$ phase. Silicon concentrations in the various phases, from high to low, are as follows: $\mu \geq \gamma \geq \kappa \geq \beta \geq \alpha$.. The $\gamma$, $\kappa$, and $\mu$ phases also share the characteristic that they are harder and more brittle than the $\alpha$ phase, and impart an appropriate hardness to the alloy so that the alloy is machinable and so that the cuttings formed by machining are less likely to damage the cutting tools as describe regarding Figure 1. Therefore, to practice the invention, each copper alloy must have at least one of the $\gamma$ phase, the $\kappa$ phase, and the $\mu$ phase, or any combination of these phases, in the $\alpha$ phase in order to provide a suitable degree of hardness to the copper alloy.

[0087] Another goal of the copper alloys of the present invention is to limit the amount of $\beta$ phase in the $\alpha$ matrix of the metal construction. It is desired to limit the $\beta$ phase to 5% or less of the total phase area because the $\beta$ phase does not contribute to either the machinability or the cold workability of the copper alloy. Preferably, the $\beta$ phase is zero in the

metal construction of the present invention, but it is acceptable to have the $\beta$ phase contribute up to 5% of the total phase area.

[0088] Therefore, the copper alloys of the present invention, as illustrated in Tables 1-8 and 10-16, are constrained to a metal construction as follows: (1) an $\alpha$ phase matrix of about 30% or more; (2) a $\beta$ phase of 5% or less; and consequently (3) any combination of the $\gamma$ phase, the $\kappa$ phase, and the $\mu$ phase totaling between 5-70% of the total phase area. In other words, the forging conditions described above and in the tables in combination with the elemental composition of the copper alloys of the present invention are constrained so that any one of: (a) $\alpha + \gamma + \kappa + \mu$ phases ($5\% \leq \gamma + \kappa + \mu \leq 70\%$), (b) $\alpha + \gamma + \kappa$ phases ($5\% \leq \gamma + \kappa + \mu \leq 70\%$), (c) $\alpha + \gamma + \mu$ phases ($5\% \leq \gamma + \mu \leq 70\%$), (d) $\alpha + \kappa + \mu$ phases ($5\% \leq \kappa + \mu \leq 70\%$), (e) $\alpha + \gamma$ phases ($5\% \leq \gamma \leq 70\%$), (f) $\alpha + \kappa$ phases ($5\% \leq \kappa \leq 70\%$), and (g) $\alpha + \mu$ phases ($5\% \leq \mu \leq 70\%$), are acceptable composite phases forming the metal construction subject to the caveat that the metal construction includes no more than 5% of the $\beta$ phase.

[0089] Lastly, it is pointed out that although metal constructions are possible where the $\gamma$, $\kappa$, and $\mu$ phases may make up more than 70% of the total phase area, the result is a copper alloy that has no problem with machinability, but has an $\alpha$ phase matrix of less than 30% which results in such a poor degree of cold workability as to render the alloy of no practical value. On the other hand, if the copper has less than 5% of the total phase area comprised of the $\gamma$, $\kappa$, and $\mu$ phases then the machinability of the copper alloy is rendered unsatisfactory. The $\beta$ phase is minimized to less than 5% of the total phase area because the $\beta$ phase does not contribute to either the machinability or cold workability of the copper alloy. In addition, because the $\alpha$ phase is the soft phase for the metal construction, and therefore has ductility, the machinability of the copper alloy is greatly improved by adding even an extremely small

amount of lead. The result is that the metal construction of the present invention utilizes the $\alpha$ phase as the matrix in which the $\gamma$ , $\kappa$, and $\mu$ phases disperse.

[0090] While the present invention has been described with reference to certain preferred embodiments, one of ordinary skill in the art will recognize that additions, deletions, substitutions, modifications and improvements can be made while remaining within the spirit and scope of the present invention as defined by the appended claims.